containing oxygen and carbon monoxide, a carbon monoxide gas, and a carbon dioxide gas, is used as the gas containing oxygen atoms and carbon atoms.

39. The semiconductor device manufacturing method according to claim 35, wherein said ashing and removing the photoresist includes setting the substrate temperature to not higher than 150°C.

40. The semiconductor device manufacturing method according to claim 35, wherein said ashing and removing the photoresist includes setting the reaction pressure to not higher than 400 m Torr.--

REMARKS

This application is a continuation, under 37 C.F.R. § 1.53(b), of U.S. Patent Application No. 09/739,905, presently allowed. In this Preliminary Amendment, Applicants have amended the Specification and Abstract, cancelled claims 1 – 20 without prejudice or disclaimer of their subject matter, and added new claims 21 – 40 to protect additional aspects of the present invention. In accordance with the requirements of 37 C.F.R. § 1.121(c)(1), Applicants provide a marked-up version of the amended specification in an attached Appendix designated "Version of Specification with Markings to Show Changes Made."

Applicants respectfully request the Examiner promptly consider and allow this application.

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If there is any fee due in connection with the filing of this Preliminary Amendment, please charge the fee to our Deposit Account No. 06-0916.

Respectfully submitted,

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Dated: June 24, 2003

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APPENDIX TO PRELIMINARY AMENDMENT OF June 24, 2003

Version of Specification with Markings to Show Changes Made

IN THE SPECIFICATION:

Please replace the paragraphs beginning on page 4, line 15, and ending on page 9, line 19, with the following new paragraphs:

[This invention has been made in view of the above problems and an object of this invention is to provide a dry etching method and semiconductor device manufacturing method for preventing modification or deformation from occurring on the side surface of grooves when a second insulating layer is removed after the second insulating layer which is patterned and contains carbon is formed on a first insulating layer containing carbon and the grooves are formed in the first insulating layer with the second insulating layer used as a mask.

In order to attain the above object, a dry etching method of a first aspect of this invention comprises the steps of sequentially laminating a first insulating layer containing carbon and a second insulating layer containing carbon on a substrate; patterning the second insulating layer into a preset shape; forming grooves in the first insulating layer by etching the first insulating layer with the second insulating layer used as a mask; and removing the second insulating layer by use of a reactive gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms without substantially modifying or deforming the side surface of the grooves formed in the first insulating layer.

It is preferable that the first insulating layer containing carbon atoms is one selected from a group consisting of a carbon layer, an organic silicon compound layer and an organic layer.

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The second insulating layer containing carbon is a photoresist, for example.

A semiconductor device manufacturing method of a second aspect of this invention comprises the steps of sequentially laminating an insulating layer and photoresist each containing carbon on a semiconductor substrate; patterning the photoresist into a preset shape; forming at least one of contact holes and a interconnection grooves in the insulating layer by etching the insulating layer with the photoresist used as a mask; ashing and removing the photoresist by use of a gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms; and depositing a metal interconnection layer in at least one of the contact holes and the interconnection grooves to form interconnections therein.

It is preferable that the insulating layer containing carbon is one of an organic silicon compound layer and an insulating layer of low dielectric constant containing carbon atoms.

A semiconductor device manufacturing method of a third aspect of this invention comprises the steps of sequentially laminating an insulating layer and a first photoresist on a semiconductor substrate; patterning the first photoresist into a preset shape; forming first interconnection grooves by etching the insulating layer with the first photoresist used as a mask; ashing and removing the first photoresist by use of a gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms; burying a carbon layer in the first interconnection grooves; laminating a second photoresist on the insulating layer to cover the carbon layer; patterning the second photoresist into a preset shape; forming second interconnection grooves by etching the carbon layer with the second photoresist used as a mask; ashing and removing the second photoresist by use of a gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms; depositing a metal interconnection layer in the second interconnection grooves to bury interconnections therein; forming a porous

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silicon oxide layer on the interlayer insulating layer to cover the interconnections and the carbon layer; and heating the carbon layer to remove the same from the interconnection grooves and provide a hollow around each of the interconnections.

It is preferable that the step of sequentially laminating an insulating layer and a first photoresist on a semiconductor substrate and the step of laminating a second photoresist on the insulating layer to cover the carbon layer further include a step of forming an antireflection layer between the insulating layer and the first or second photoresist.

In the first to third aspects, it is preferable to realize the following items.

(1) Among the gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms, the atomic percentage of carbon in a gas containing oxygen atoms and carbon atoms is 1/3 or more of the atomic percentage of oxygen.

(2) As gas containing oxygen atoms and carbon atoms among the gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms, a gas selected from a gas containing oxygen and carbon dioxide, a gas containing oxygen and carbon monoxide, a carbon monoxide gas and a carbon dioxide gas is used.

(3) The step of ashing and removing the photoresist includes a step of setting the substrate temperature of 150°C or less.

(4) The step of ashing and removing the photoresist includes a step of setting the reaction pressure to 400 m Torr or less.

Conventionally, the operation for stripping the photoresist after forming the insulating layer (for example, Low-k layer) containing carbon atoms is effected by a plasma ashing process by use of an oxygen gas, but according to this method, the side surfaces of the Low-k layer are also side-etched at the same time as the upper portion thereof is etched, and thus there occurs a

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problem that a CD bias occurs. This is because an isotropic oxygen radical component enters the contact hole formed in the Low-k layer at the time of plasma ashing of the photoresist by use of an oxygen gas and etching of the Low-k layer proceeds starting from a portion which is in contact with the radical based gas.

This invention is characterized in that a second insulating layer (for example, photoresist) containing carbon atoms which is formed on a first insulating layer (for example, Low-k layer) containing carbon atoms is ashed by use of a gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms in a method for dry-etching a coating by use of a reactive gas which is activated as described above. By using the above gas, a phenomenon that the first underlying insulating layer is oxidized and the carbon atoms are removed can be suppressed and only the second insulating layer containing carbon atoms can be efficiently removed by ashing. Thus, formation of a modified layer on the side surface of the groove in the first insulating layer and the side etching thereof can be prevented.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.]

<u>A dry etching method according to a first aspect of the invention comprises: sequentially laminating a first insulating layer containing carbon and a second insulating layer containing carbon on a substrate; patterning the second insulating layer to form a mask; forming grooves in the first insulating layer by etching the first insulating layer with the second insulating layer used as a mask such that each of the grooves has a side surface and a bottom surface in the first</u>

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insulating layer; and removing the second insulating layer by use of a reactive gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms.

A semiconductor device manufacturing method according to a second aspect of the invention comprises: sequentially laminating an insulating layer and a photoresist each containing carbon on a semiconductor substrate; patterning the photoresist to form a mask; forming interconnection grooves in the insulating layer by etching the insulating layer with the photoresist used as a mask such that each of the interconnection grooves has a side surface and a bottom surface in the insulating layer; ashing and removing the photoresist by use of a gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms; and depositing a metal interconnection layer in the interconnection grooves to form interconnections therein.

A semiconductor device manufacturing method according to a third aspect of the invention comprises: sequentially laminating an insulating layer and a first photoresist on a semiconductor substrate; patterning the first photoresist to form a mask; forming first interconnection grooves by etching the insulating layer with the first photoresist used as a mask; ashing and removing the first photoresist by use of a gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms; burying a carbon layer in the first interconnection grooves; laminating a second photoresist on the insulating layer to cover the carbon layer; patterning the second photoresist to form a mask; forming second interconnection grooves by etching the carbon layer with the second photoresist used as a mask such that each of the second interconnection grooves has a side surface and a bottom surface in the carbon layer; ashing and removing the second photoresist by use of a gas containing carbon atoms and at least one of oxygen atoms, hydrogen atoms and nitrogen atoms; depositing a metal interconnection

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layer in the second interconnection grooves to bury interconnections therein; forming a porous silicon oxide layer on the interlayer insulating layer to cover the interconnections and the carbon layer; and heating the carbon layer to remove the same from the interconnection grooves and provide a hollow around each of the interconnections.

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